

**SIZING OF AN ELECTROMAGNETIC TRANSPONDER SYSTEM FOR AN
OPERATION IN EXTREME PROXIMITY**

Background Of The Invention

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1. Field of the Invention

The present invention relates to systems using electromagnetic transponders, that is, transceivers (generally mobile) capable of being interrogated in a contactless and wireless manner by a unit (generally fixed), called a read and/or write terminal. The present invention more specifically relates to transponders having no independent power supply. Such transponders extract the power supply required by the electronic circuits included therein from the high frequency field radiated by an antenna of the read/write terminal. The present invention applies to such transponders, be they read only transponders, that is, adapted to operate with a terminal only reading the transponder data, or read/write transponders, which contain data that can be modified by the terminal.

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2. Discussion of the Related Art

Systems using electromagnetic transponders are based on the use of oscillating circuits including a winding forming an antenna, on the transponder side and also on the read/write terminal side. These circuits are intended to be coupled by a close magnetic field when the transponder enters the field of the read/write terminal.

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Fig. 1 very schematically shows, in a simplified way, a conventional example of a data exchange system between a read/write terminal 1 and a transponder 10.

Generally, unit 1 is essentially formed of an oscillating circuit formed of an inductance L1 in series with a capacitor C1 and a resistor R1, between an output terminal 2 of an amplifier or antenna coupler (not shown) and a reference terminal 3 (generally, the ground). The antenna coupler belongs to a circuit 4 for controlling the oscillating circuit and exploiting received data including, among others, a modulator-demodulator and a microprocessor for processing the control signals and the data. In the example shown in Fig. 1, node 5 of connection of capacitor C1 with inductance L1 forms a terminal for sampling a data signal received from transponder 10 for the demodulator. Circuit 4 of the terminal generally communicates with different input/output circuits (keyboard, screen, means of transmission to a provider, etc.) and/or processing circuits,

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not shown. The circuits of the read/write terminal draw the power required by their operation from a supply circuit (not shown) connected, for example, to the electric supply system.

A transponder 10, intended for cooperating with a terminal 1, essentially includes
5 an inductance L2, in parallel with a capacitor C2 between two input terminals 11, 12 of a circuit 13 of control and processing of transponder 10. Terminals 11, 12 are, in practice, connected to the input of a rectifying means (not shown), the outputs of which define D.C. supply terminals of the circuits internal to the transponder. In Fig. 1, the load formed of the circuits of transponder 10 on the oscillating circuit have been modeled by a
10 resistor R2, shown in dotted lines, in parallel with inductance L2 and capacitor C2.

The oscillating circuit of terminal 1 is excited by a high-frequency signal (for example, 13.56 MHz) intended for being sensed by a transponder 10. When transponder 10 is in the field of terminal 1, a high-frequency voltage is generated across terminals 11, 12 of the transponder's resonant circuit. This voltage, after being rectified, is intended for
15 providing the supply voltage of electronic circuits 13 of the transponder. These circuits generally essentially include a microprocessor, a memory, a demodulator of the signals possibly received from terminal 1, and a modulator for transmitting information to the terminal.

The data transmission from transponder 10 to terminal 1 is generally performed
20 by modifying the load of oscillating circuit L2, C2, so that the transponder draws a lesser or greater amount of power from the high-frequency magnetic field. This variation is detected, on the side of terminal 1, because the amplitude of the high-frequency excitation signal is maintained constant. Accordingly, a power variation of the transponder translates as a variation of the current amplitude and phase in antenna L1.
25 This variation is then detected, for example, by a measurement of the signal of terminal 5, either by means of a phase demodulator, or by means of an amplitude demodulator. The load variation on the transponder side is generally performed by means of an electronic switch for controlling a resistor or a capacitor modifying the load of the oscillating circuit. The electronic switch is generally controlled at a so-called sub-carrier
30 frequency (for example, 847.5 kHz), much smaller (generally with a ratio of at least 10) than the frequency of the excitation signal of the oscillating circuit of terminal 1.

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In the case of a phase demodulation by terminal 1, its modulator detects, in the sub-carrier half-periods when the electronic switch of the transponder is closed, a slight phase shift (by a few degrees, or even less than one degree) of the high-frequency carrier with respect to a reference signal. The demodulator output then provides a signal that is an image of the control signal of the electronic switch of the transponder, which can be decoded to restore the transmitted binary data.

To obtain a proper operation of the system, the oscillating circuits of terminal 1 and of transponder 10 are generally tuned on the carrier frequency, that is, their resonance frequency is set, for example, to the 13.56-MHz frequency. This tuning aims at maximizing the power transfer to the transponder, generally, a card of credit card size integrating the different transponder components.

The fields of application of electromagnetic transponders (for example, electronic purses, prepaid pass cards, etc.) may make it desirable to guarantee that a transponder only operates in a predetermined distance relation with a read/write terminal, more specifically, in extreme proximity, that is, in a relation generally defined by a distance smaller than 1 cm separating the respective antennas of the transponder and of the read/write terminal.

For example, in applications such as an electronic purse, the transaction security must be guaranteed, and pirates must then be unable to place a parasitic read terminal in the vicinity of an authorized terminal to intercept the information from the transponders using this authorized terminal. In this case, it must be guaranteed that a transponder will only operate in a relation of extreme proximity with the terminal.

However, in conventional systems, the remote supply of the transponders exhibits a gap, that is, a loss of remote supply power when the transponder is very close to the terminal. Among current solutions to solve this problem, a minimum interval is generally forced between antennas L1 and L2, for example by interposing a block between antenna L1 and the surface of the package before which the transponder is to pass. A disadvantage of this solution is that the coupling then no longer really corresponds to an extreme proximity, which makes the system particularly vulnerable to piracy by leaving a greater available range to the pirate.

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Another known solution is, for an operation in extreme proximity, to increase the back-modulation resistance of the transponder. The aim then is to make the back modulation invisible by the terminal if the transponder is too far, the load variation becoming impossible to detect by the terminal demodulator. A disadvantage of this solution is that, in case a pirate terminal has been designed to be able to provide a sufficient power and to be provided with a very sensitive demodulator, the transponder is then visible, even from far away, by this pirate terminal.

Summary Of The Invention

10 The present invention aims at providing a solution to the need for operation in extreme proximity of electromagnetic transponder systems.

The present invention aims, in particular, at providing a solution that enables structurally dedicating a transponder and/or a terminal to an operation in extreme proximity.

15 More generally, the present invention aims at providing a solution that enables structurally dedicating a transponder and/or a terminal to an operation in a relation where the antennas are at a distance smaller than a predetermined value from each other.

The present invention also aims at providing a solution that is particularly simple to implement for the manufacturer and that is reliable in time.

20 To achieve these and other objects, the present invention provides an electromagnetic transponder of the type including a parallel oscillating circuit adapted to being excited by a series oscillating circuit of a read/write terminal when the transponder enters the field of the terminal, wherein the components of the oscillating circuit of the transponder are sized so that the coupling coefficient between the respective oscillating
25 circuits of the terminal and of the transponder rapidly decreases when the distance separating the transponder from the terminal becomes greater than a predetermined value.

According to an embodiment of the present invention, the predetermined value corresponds to 1 centimeter.

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According to an embodiment of the present invention, the oscillating circuit of the transponder has no capacitor, the stray capacitance of the inductance performing the function of the capacitive element for the oscillating circuit.

According to an embodiment of the present invention, an inductance of the
5 parallel oscillating circuit is increased or maximized, a capacitance of this oscillating circuit being decreased or minimized.

According to an embodiment of the present invention, inductance L2 of the parallel oscillating circuit is chosen so that the following relation is respected:

$$k_{opt} = \sqrt{\frac{R1L2}{R2L1}},$$

10 where k_{opt} represents the coupling coefficient providing a maximum voltage across the parallel oscillating circuit, where R1 represents the series resistance of the series oscillating circuit, where R2 represents the equivalent resistance of the transponder brought in parallel on inductance L2, and where L1 represents the inductance of the series oscillating circuit.

15 According to an embodiment of the present invention, the components of the oscillating circuit of the transponder are sized based on an operating point at a zero distance, chosen to correspond to a coupling coefficient smaller than an optimal coupling coefficient respecting the following relation:

$$V_{2max}(k_{opt}) = \sqrt{\frac{R2}{R1}} \frac{V_g}{2},$$

20 where V_{2max} represents the voltage across the parallel oscillating circuit for the optimal coupling between the oscillating circuits, where R1 represents the series resistance of the series oscillating circuit, where R2 represents the equivalent resistance of the transponder brought in parallel on its oscillating circuit, and where V_g represents the excitation voltage of the series oscillating circuit.

25 According to an embodiment of the present invention, the number of turns of the inductance of the oscillating circuit of the transponder ranges between 5 and 15.

According to an embodiment of the present invention, the respective values of the capacitance and of the inductance of the parallel oscillating circuit range between 5 and 100 pf and between 2 and 25 μ H.

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The present invention also provides a terminal for generating an electromagnetic field adapted to cooperating with at least one transponder when said transponder enters this field, including a series oscillating circuit for generating the electromagnetic field, this series oscillating circuit being sized so that the coupling coefficient between the
5 respective oscillating circuits of the terminal and of the transponder strongly decreases when the distance separating the transponder from the terminal becomes greater than a predetermined value.

According to an embodiment of the present invention, the components of the oscillating circuit of the terminal are sized to fulfill the operating conditions of the
10 transponder.

According to an embodiment of the present invention, the inductance of the terminal's series oscillating circuit includes a single turn.

The present invention further relates to a system of contactless electromagnetic transmission between a terminal and a transponder.

15 The foregoing objects, features and advantages of the present invention, will be discussed in detail in the following non-limiting description of specific embodiments in connection with the accompanying drawings.

Brief Description Of The Drawings

20 Fig. 1, previously described, very schematically shows a read/write terminal and an electromagnetic transponder of the type to which the present invention applies; and

Fig. 2 shows an example of variation of the voltage across the oscillating circuit of a transponder according to the distance separating it from a terminal.

Detailed Description

25 For clarity, only those elements necessary to the understanding of the present invention have been shown in the drawings and will be described hereafter. In particular, the circuit for controlling and exploiting the oscillating circuits of the transponder and of the terminal have not been detailed.

30 A feature of the present invention is to provide a specific sizing of the oscillating circuit of an electromagnetic transponder so that said transponder is structurally

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dedicated to an operation in which it is at a distance smaller than a predetermined value from a read/write terminal, preferably, in extreme proximity, that is, at less than 1 cm.

The notion of distance to which the present invention refers is the distance separating respective antennas L1, L2 (Fig. 1) of a transponder 10 and of a terminal 1.

5 The present invention thus provides placing, preferably by respective sizings of the oscillating circuits of the transponder and of the antenna, the system operating point to guarantee the desired range operation at the tuning frequency, that is, when the resonance frequencies of the oscillating circuit substantially correspond to the remote supply carrier frequency (for example, 13.56 MHz).

10 Fig. 2 shows the variation of voltage V2 across terminals 11, 12 of the transponder according to distance d separating the transponder from a read/write terminal.

The curve of Fig. 2 can also be considered as showing the variation of voltage V2 according to coupling coefficient k between the oscillating circuits of the transponder and of the terminal. Indeed, the coupling between the oscillating circuits is a function of
15 the distance separating the antennas. More specifically, coupling coefficient k is, as a first approximation, proportional to 1-d. Accordingly, in the following description, reference will be made either to distance or to the coupling coefficient as the abscissa of the characteristic of Fig. 2. The x-axis represents a distance d increasing towards the right
20 of the drawing and a coupling coefficient k increasing towards the left of the drawing.

Voltage V2 exhibits a maximum V2max for an optimal value of coupling coefficient kopt. This value corresponds to the smallest distance separating the two antennas for which voltage V2 is maximum when the frequency corresponds to the resonance frequency of the oscillating circuits. This value corresponds, according to the
25 present invention, to a short distance. For a given frequency and sizing determining the operating conditions, voltage V2 decreases on either side of the optimal coupling position.

The curve exhibits a reversal point for a coupling value of $k_{opt}\sqrt{3}$, that is, for a distance smaller than the optimal coupling position. On the smaller distance side, the
30 curve tends towards an asymptote at a minimum voltage position V2min. On the greater distance side at the optimal coupling position, the decrease of voltage V2 is stronger.

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The relation between optimal coupling coefficient k_{opt} and the components of the oscillating circuits is the following:

$$k_{opt} = \sqrt{\frac{R_1 L_2}{R_2 L_1}}.$$

A coupling coefficient k equal to one corresponds to the theoretical limiting value. Accordingly, coefficient k_{opt} is, in practice, always smaller than 1.

More generally, coupling coefficient k is provided by formula $k = m/\sqrt{L_1 L_2}$, where m represents the mutual inductance between the oscillating circuits. This mutual inductance essentially depends on the geometry of antennas or inductances L_1 and L_2 .

A feature of the present invention is to determine, by means of the respective values of the oscillating circuit components, a distance operating point such that moving away from this operating point strongly decreases the coupling between the oscillating circuits.

Thus, for an operation in extreme proximity, the oscillating circuits will be sized so that optimal coupling coefficient k_{opt} is as much as possible to the left of the drawing, that is, towards small distances. Since this optimal coupling is theoretical and inaccessible in practice, two possibilities for placing the real operating point are then available in terms of coupling and distance, by the sizing of the oscillating circuits.

According to the present invention, the zero distance point will be chosen to correspond, while being as close as possible to the optimal coupling point, to a coupling coefficient smaller than the optimal coefficient and adapted to the minimum voltage V_{2tr} required for a proper transponder operation. This amounts to placing an operating point at a zero distance to the right of the optimal coupling position on Fig. 2. This point corresponds to a real maximum coupling k_{max} . Coefficient k_{max} depends on the respective geometries of antennas L_1 and L_2 and is, of course, included between 0 and 1. In practice, it should be noted that the real maximum coupling coefficient k_{max} between two oscillating circuits generally does not exceed 0.7.

An advantage then is to be located in the portion of the voltage-distance characteristic having a steep slope. Thus, as soon as the distance moves away from the operating point by the increase of the interval between the two oscillating circuits, the coupling coefficient strongly decreases so that the transponder is then no longer supplied.

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It should of course be noted that, since the distance cannot be negative, the determined operation point then is the point for which the coupling is maximum in the system configuration.

Preferably, the real maximum coupling point will be chosen so that the
5 corresponding voltage V_2 ($V_2(k_{\max})$) is slightly greater than the minimum operating voltage V_{2tr} of the transponder. For simplification, level V_{2tr} has been indicated for coupling position k_{\max} in Fig. 2. As a specific example of embodiment if voltage V_{2tr} is 5 volts for a coefficient k_{\max} of 0.2, voltage V_2 becomes 2.5 volts for a coefficient k of 0.1.

10 Preferably, the highest possible value of inductance L_2 of transponder 10 is chosen to have, at the resonance frequency (13.56 MHz), the smallest possible capacitance C_2 , for example on the order of some ten picofarads.

An advantage of such an embodiment is that capacitor C_2 thus is easier to integrate.

15 Another advantage is that the reactive currents, which are a source of dissipation in transponder 10, are thus decreased.

It should be noted that, while in conventional systems the value of inductance L_2 of the transponder is desired to be increased to increase the system range, the present invention conversely provides to increase this inductance to reduce or minimize the
20 range, to obtain a dedicated operation in extreme proximity.

Searching the greatest possible inductance L_2 goes along with searching the highest possible coupling for the zero distance. Similarly, it will be desired to reduce or minimize the value of equivalent resistance R_2 , still for increasing the coupling coefficient in extreme proximity.

25 It should be noted that the search for the greatest possible inductance L_2 corresponds to an increase of the number of turns of this inductance (for example, of the number of conductive turns in antenna L_2 formed on the chip card forming the transponder). This increase of the number of turns increases the parasitic resistance of inductance L_2 . However, the increase of the parasitic series resistance corresponds,
30 brought in parallel on the oscillating circuit, to a decrease of resistance R_2 . This is thus favorable to decrease resistance R_2 .

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An advantage of reducing or minimizing the value of capacitor C2 is that this decreases the quality factor of the transponder. Indeed, the quality factor of a parallel resonant circuit is equal to $\omega R^2 C_2$, where ω represents the pulse of the oscillating circuit. Now, the lower the quality factor, the more the data rate can be increased between the
5 transponder and the terminal.

A data-rate increase improves the system security with respect to a pirate read terminal. Indeed, a pirate reader will have to have a high quality factor to attempt to intercept the information coming from the transponder while it will not be in extreme proximity therewith. Having a high quality factor, the pirate reader will not be able to
10 read the information with a high data-rate and, accordingly, will be inefficient.

Further, decreasing the quality factor on the transponder side discards the problem of the remote supply gap in conventional systems in extreme proximity. Indeed, the operation then is closer to that of a transformer.

A feature of a preferred embodiment of the present invention is, to reduce or
15 minimize the value of capacitance C2, to eliminate the use of a capacitor in parallel on inductance L2 and to have the stray capacitance of the inductance perform the function of this capacitor. The present inventors have indeed acknowledged that this stray capacitance is the minimum value and that this minimum value varies little with the variations of the number of turns of the inductance. Accordingly, the inductance can then
20 be sized so that its natural resonance frequency corresponds to the frequency of its carrier. For example, for a transponder of credit card size, an antenna of 10 turns on the card provides an inductance on the order of 13.5 μH , with a stray capacitance of some ten picofarads. An advantage of this embodiment is that the surface area required to form the capacitor is saved. Further, any reactive current is then eliminated.

25 According to a preferred embodiment of the present invention, the respective values of the different components are determined as follows.

First, the application and the energetic needs of the transponder determine voltage V2tr to be obtained by remote supply. For a given excitation voltage Vg of the oscillating circuit of the terminal, the voltage V2 recovered by the transponder is a function of the
30 respective values of series resistance R1 of the terminal and of equivalent resistance R2 of the transponder in parallel on its oscillating circuit. The value of resistance R2 can be

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evaluated based on the transponder components (microprocessor, regulator, etc.) that determine the remote supply need to be maintained.

At theoretical optimal coupling point k_{opt} , voltage V_{2max} is provided by the following relation:

$$V_{2max}(k_{opt}) = \sqrt{\frac{R_2}{R_1}} \frac{V_g}{2} .$$

More generally, the relation linking voltage V_2 to coupling coefficient k can be written as:

$$V_2(k) = \frac{k R_2 V_g \sqrt{\frac{L_1}{L_2}}}{R_1 + k^2 \frac{L_1}{L_2} R_2} .$$

After determining the voltage V_2 to be obtained across capacitor C_2 , capacitor C_2 is sized to the smallest possible value to ease its integration.

Then, inductance L_2 of the oscillating circuit is determined according to the desired resonance frequency, based on the relation:

$$L_2 = \frac{1}{C_2 \omega^2} .$$

Knowing inductance L_2 , the value to be given to the inductance of antenna L_1 of the terminal to optimize the system can be determined. The relation linking these two values for the curve of Fig. 2 to be respected is, at the tuning, that is, for a sizing setting the resonance frequency to the remote supply carrier frequency:

$$L_1 = \frac{R_1 L_2}{R_2 k^2} .$$

Preferably, the value of inductance L_1 is chosen to be as small as possible, that is, by minimizing its number of turns. Thus, according to the present invention, the number of turns of the terminal is relatively small, preferably 1, and the number of turns of the transponder is relatively high, preferably between 5 and 15 for a credit card format.

Preferably, a transponder of the present invention uses a single-halfwave rectification of voltage V_2 . Indeed, since the system of the present invention is provided to operate at a smaller range, the required power is also smaller.

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Preferably, the terminal will be provided with a resistance R1 as high as possible to obtain an optimal coupling (smaller than or equal to 1) at the shortest possible distance.

As a specific example of embodiment, for a 13.56-MHz carrier frequency and for
5 a value of 10 picofarads for capacitor C2, an antenna L2 having an inductance of
approximately 13.5 microhenrys will be used. If the transponder's microprocessor
requires a minimum voltage on the order of 4 volts to operate, a voltage V2 of
approximately 5 volts will be chosen for a null distance position. The preferred ranges of
values are, for example, a capacitor C2 of given value included between 5 and 100
10 picofarads and an inductance L2 of given value included between 2 and 25 microhenrys.

It should be noted that the fact of structurally determining the respective values of
the components of the oscillating circuits of the terminal and the transponder is not
disturbing. Indeed, in most applications, a given transponder type is dedicated to a
terminal. In particular, the operating characteristics of electromagnetic transponder
15 systems are generally submitted to standards. Accordingly, it is not disturbing to
definitively determine the relations between the oscillating circuits of a terminal and of a
transponder. Conversely, this is an advantage of the present invention since risks of
unauthorized intervention on the transponder for piracy are thus avoided.

An advantage of the present invention is that it enables forming transponders and
20 systems dedicated to an operation in extreme proximity.

Another advantage of the present invention is that it fulfils the strictest
requirements to avoid the piracy of a transponder.

Of course, the present invention is likely to have various alterations,
modifications, and improvements which will readily occur to those skilled in the art. In
25 particular, the choice of the values of the components of the oscillating circuits is within
the abilities of those skilled in the art based on the functional indications and on the
relations given hereabove, according to the application and, in particular, to the carrier
frequency on which these oscillating circuits are to be tuned. Further, it should be noted
that the present invention does not alter the respective operations of the transponder and
30 of the terminal as concerns the digital processing circuits.

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Among the applications of the present invention are readers (for example, access control terminals or porticoes, automatic dispensers, computer terminals, telephone terminals, televisions or satellite decoders, etc.) of contactless chip cards (for example, identification cards for access control, electronic purse cards, cards for storing information about the card holder, consumer fidelity cards, toll television cards, etc.), as well as such chip cards.

Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within the spirit and the scope of the present invention. Accordingly, the foregoing description is by way of example only and is not intended to be limiting. The present invention is limited only as defined in the following claims and the equivalents thereto.

What is claimed is:

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